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AREA ILLUMINATED LEAKY CABLE INTRUSION SENSOR SYSTEM, (U)

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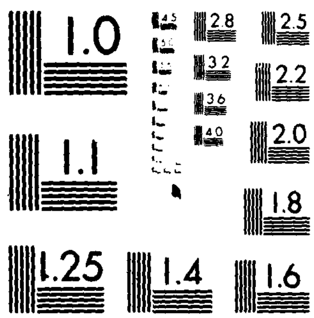
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AREA ILLUMINATED LEAKY CABLE INTRUSION SENSOR SYSTEM

K.V.N. Rao
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N.V. Karas

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Sponsored by Defense Nuclear Agency under Subtask B99QAXRB201 Work Unit 02 Entitled "RF Area Intruder Detection and Locating System" (FY79)

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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Leaky coax
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The single wire leaky coax cable/antenna(s) concept has been modified to include the detection, location, and tracking of intruders in large and small zones. This modified concept has been designated as the "Area Illuminated Leaky Cable Sensor." The zones may be large areas such as military bases or small areas containing one or more valuable resources. The zone to be protected is illuminated with rf energy from a transmitter(s) that illuminates one or more strategically placed leaky cable sensors in a prescribed sequence

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20. Abstract (Continued)

or simultaneously. Outputs from specific sensors indicate the track of the intruder as he moves by or through each sensor's detection field. Experimental results show that tracking is feasible. Also presented are particular operating characteristics of several configurations.

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Area Illuminated Leaky Cable Intrusion Sensor System

1. INTRODUCTION

The Defense Nuclear Agency and Department of Defense have the common need to protect areas containing valuable resources.[1] Several types of sensor systems detect the intrusions that occur at the perimeters of these areas. Examples of these are: 1) vibration sensors attached to fences,[2] 2) ultrasonic beam sensors,[3] 3) enclosed sensors buried in the ground,[4] 4) microwave beam breakers,[5] 5) sensors using laser beams at visible and infrared wavelengths,[6] 6) antipersonnel radars operating at UHF and microwave bands,[7] and 7) leaky coaxial cables[8,9] operating at VHF and UHF bands. All of these sensor systems have advantages and disadvantages depending upon 1) the type of resource[1,2] and its environment and 2) the spatial and the temporal extent to which the resources need protection.[1] Each of these sensor systems also protects resources against one or more types of intrusions. Ideally, the sensor system should detect, identify, locate, and track the valid intrusion until the security forces take action.

At the Electromagnetic Sciences Division of Rome Air Development Center located at Hanscom AFB, Bedford, Massachusetts, a novel intrusion sensor system has been conceived and developed in the past few years.[10] Numerous reports describing various aspects of this sensor system are available.[11–15] This sensor

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(Received for publication 25 August 1981)

Because of the large number of references cited above, they will not be listed here. See References, page 25.

system, called Single Wire Individual Resource Protection Sensor, abbreviated as "SWIRPS," consists of three subsystems: 1) a leaky coax cable excited with rf energy, which encircles the resource, 2) one or more antennas to sense the disturbance of the ambient field caused by the intruder at the leaky coax cable, and 3) suitable signal processor. A theoretical description of the operation of SWIRPS and experimental results obtained on detection of intrusions are contained in RADC technical reports.[14, 15] A general description on the study of leaky-feeder principles and the propagation characteristics of a loosely braided coax cable in free space is given by Martin[16] and Fernandes.[17] In this report, we describe the advancement of the SWIRPS concept to detect, locate, and track intruders in large and small areas. An in-house experimental and theoretical study was initiated to investigate the detection and tracking of human intruders and vehicles such as automobiles and vans in an area less than approximately 20,000 m^2 of a rectangular patch of 100 m by 200 m. In Section 2 of this report we summarize the earlier results of SWIRPS and make some brief comments on the SWIRPS and similar systems. Section 3 contains the description of the concept of modifying SWIRPS for tracking intruders. Section 4 contains a discussion of the experimental results. In Section 5 we included the applications of this modified SWIRPS for tracking purposes.

2. SUMMARY OF EARLIER RESULTS ON SWIRPS

The SWIRPS consists of a length of leaky coax cable that acts as a distributed transmitting antenna deployed on the ground encircling a parked aircraft or any other valuable resource. One or more appropriately located monopole antennas positioned on the ground receive the rf energy emanating from the leaky coax cable. An intruder crossing the sensor cable disturbs the surface electromagnetic fields at the cable. The disturbed fields induce in the receiving antennas an rf signal whose amplitude and phase are different from the one in the absence of an intruder. This disturbed signal, when suitably processed, produces an alarm to communicate to the responsive forces. The SWIRPS has been tested when the sensor surrounded parked aircraft such as B52 or C5A, automobiles, vans, and trucks. A theoretical expression for the power received by a monopole as an intruder walks along the rf excited leaky coax cable, or crosses it has been derived by Poirier and Kushner.[14] Their phenomenological theory explained the

16. Martin, D.J.R. (1975) A general study of the leaky feeder principle, The Radio and Electronic Engineer 45(No. 5):205-214.

17. Fernandes, A.S. de C. (1979) Propagation characteristics of a loose braid coaxial in free space, The Radio and Electronic Engineer 49(No. 5):255-260.

experimental results. As mentioned by these authors, the precise structure of the fields around the leaky cable and the interaction of these fields with the intruder were not known. However, based upon the assumption that the phase and amplitude of the scattered field by the intruder is proportional to the field in which the intruder is immersed, they have successfully predicted the response of the SWIRPS system to an intruder. This theory has been verified when the leaky coax cable was laid on the ground in circular or rectangular configurations with a monopole at the center of the configuration. It should be mentioned that the presence of the lossy earth beneath the cable and large metallic resources such as aircraft are not included in the theory. However, the experimentally observed response of the intruder crossing the rf excited leaky coax cable, as seen by the monopole, both in the presence of the earth and large aircraft was in reasonable agreement with that predicted by the theory. The theory has been extended to include a single off-center antenna or multiple antennas. The theoretical predictions and experimental observations were again in reasonable agreement.[15] The results of the experimental tests performed using SWIRPS for protecting a large aircraft such as the C-5A are described by Karas, et al.[13, 15, 18] It should be emphasized that in all these tests the leaky coax cable was used as a distributed rf transmitting sensor and the monopole antenna as the receiving element. Workers at the Department of Electrical Engineering, Queens University, Kingston, Ontario, Canada, have used a similar system, but with the antenna radiating the rf energy and the disturbance of rf fields by the intruder detected by the leaky coax cable encircling the antenna.[19]

3. MODIFICATION OF SWIRPS FOR TRACKING INTRUDERS

The SWIRPS can be expanded to locate intruders in large and small areas. This new concept, Area Illuminated Leaky Cable Sensor (AILCS), provides a method for maintaining surveillance of any zones containing valuable resources in addition to detecting and locating intrusions into the zone. These zones may be large areas, such as military bases, or small areas containing one or more resources of importance. The concept consists of illuminating the zone to be protected with rf energy from a transmitter or transmitters. This energy is radiated

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18. Poles, L.D., Rao, K.V.N., Karas, N.V., Antonucci, J. (1981) VHF Intruder Detection Technique: Tests on a C5A Aircraft, RADC-TR-81-44, AD A103 944.

19. Performance Characteristics of Leaky Coaxial Cables, Final Report, USAF Contract No. F19628-77-C-0249, CCC Contract No. 7SU77-00317, Department of Electrical Engineering, Queen's University, Kingston, Ontario, Canada.

to the rf sensors such as leaky coax cables that are placed at the desired locations. Intrusions occurring at or in the vicinity of the sensor alters the rf energy it receives. The transmitting antenna may illuminate several receiving sensors within a designated area in a prescribed time sequence or simultaneously. By monitoring the outputs from individual sensors, in different channels of a receiver or on a time-sharing basis in a single channel, an intruder can be located and tracked as he moves through each sensor's zone of detection.

An artist's sketch of two system configurations that may be used in small or large areas is shown in Figures 1a and 1b. In the first configuration shown in Figure 1a, one transmitting antenna illuminated several resources. In the second configuration, shown in Figure 1b, several transmitting antennas are used, each illuminating the resources within its own defined area. Note that these areas may be contiguous with other illuminated areas or may be widely separated. The choice of the number of the transmitting antennas and the number of sensors needed will be dictated by the size of the area and the number of resources to be protected. These two sketches are reproduced here from the disclosure and record of invention submitted by Karas, et al.[20]

Figure 2 shows a typical layout of the experimental setup. In this figure we show a horizontal monopole antenna (0.75 m long) located approximately 15 m above the ground on the roof of a three story building. A vertical monopole is located at ground level approximately 50 m from the building. This second monopole (also 0.75 m long), previously utilized for testing SWIRPS, is located at the center of two concentric CERT leaky coax cable loops whose circumferences are 150 m and 75 m, respectively. A third loop, not shown in the sketch, whose circumference is 250 m is buried at a depth of about 0.3 m. In addition, short sections of coax cables (40 m and 75 m long) are placed on the ground directly under the monopole on the roof. These short sections were placed either in circular configurations as loops or as straight sections, perpendicular to the building. Experiments were performed utilizing these leaky coax cable configurations, to study the following aspects:

1. To demonstrate that an intruder can be detected in small identifiable subareas (for example, A_1 or A_2 shown in Figure 2) several of which constitute the area to be protected.

2. To investigate the electromagnetic disturbances caused by intruders crossing leaky coax cables that are illuminated from distant rf sources.

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20. Rao, K.V.N., Karas, N.V., and Poirier, J.L. (1980) Intruder Detection System Having Multiple Discrete RF Sensor Elements Illuminated by a Remote RF Transmitter, AF Invention No. 13,841.

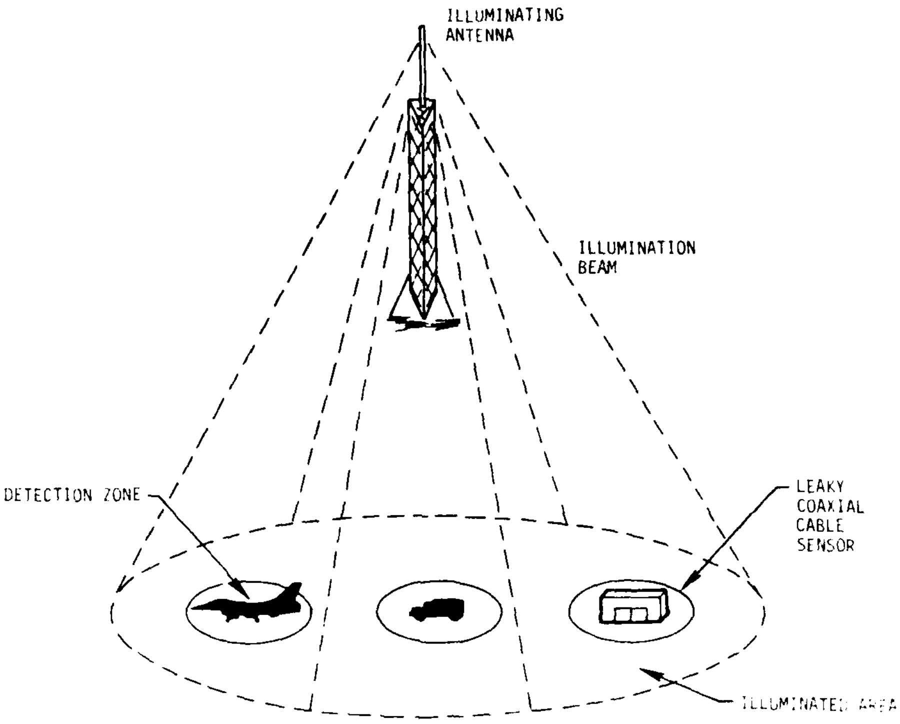

Figure 1a. Illumination Detection System for Small Areas

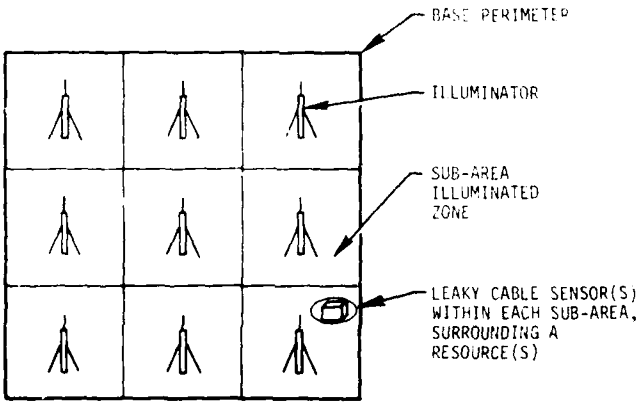

Figure 1b. Illumination Detection System for Large Areas

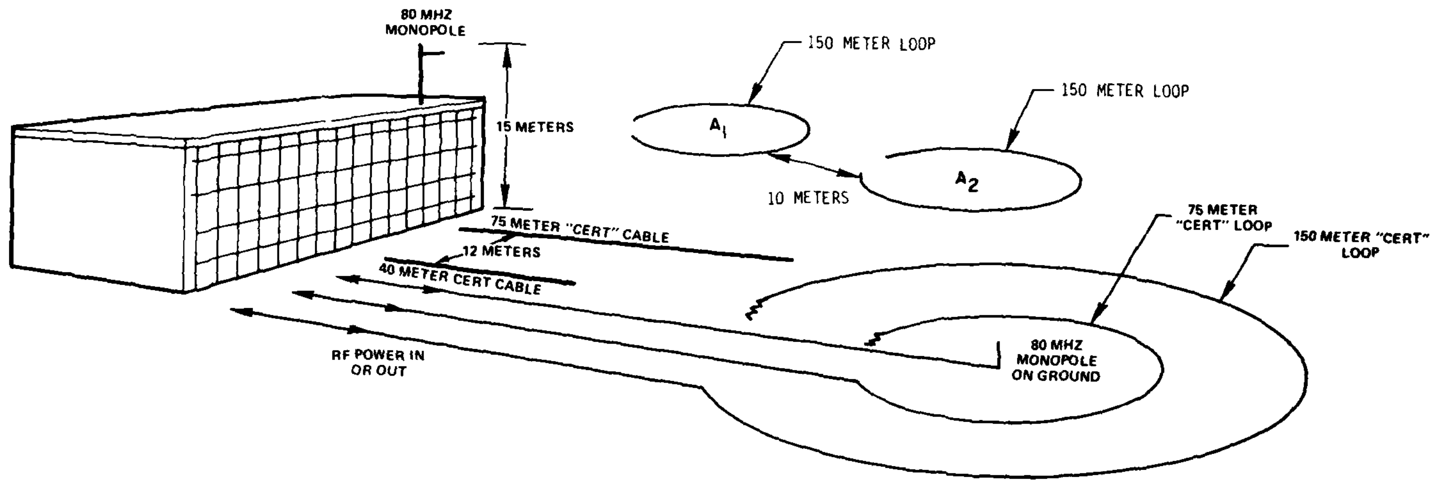

Figure 2. Typical Layout of Experimental Area Illuminated Leaky Cable Sensor System

3. To investigate the mutual coupling of electromagnetic energy via the intruder between adjacent leaky coax cables illuminated from distant rf transmitting antennas.

4. To understand the electromagnetic interaction among intruder-leaky coax cable-monopole antenna systems.

5. To observe the effects on the response of SWIRPS to electronic switching of rf energy among several leaky coax cables or between terminals of a single leaky cable.

4. EXPERIMENTAL RESULTS ON RF ILLUMINATION OF LEAKY COAX CABLES

In this section we present the experimental results obtained when an intruder walked along a leaky coax cable that is used in the modified SWIRPS system described earlier. Several experiments were performed to study the different aspects listed in Section 3.

4.1 Coupling of Intruder Induced Ambient Signal Disturbance Between Concentric Leaky Coax Cables

As described in Section 2 and shown in Figure 1, an intruder can be located as he crosses each of several leaky coax cable configurations that are illuminated from a distant transmitting antenna. In Figures 3a and 3b are shown the experimental results when an intruder made a circumferential walk in a system similar to the conventional SWIRPS system.[11] Results shown in this figure are obtained from circumferential walks on the 150 m loop (shown in Figure 2), which was fed with 10 mW of rf energy at 80 MHz from a HP8505 network analyzer, amplified by a Boonton 230A amplifier to 2 W. The rf energy received by the monopole located at the center of the loop is compared with a reference signal whose amplitude and phase are suitably adjusted. With the trace labeled -54 dBm (Figures 3a and 3b) is the magnitude of the signal received from the monopole antenna in the absence of the intruder. In this and other experiment traces shown hereafter, a downward deflection of the trace indicates a decrease in the power level of signal received at the antenna. For scaling purposes, relative changes of the signal power by ±10 dB are also shown. The intruder stopped for a few seconds at 90°, 180°, 270°, and 360° azimuth positions. As can be seen in the Figure 3a the signal level changes as the intruder walks along the cable. When the intruder stops, the signal level remains at that level until the intruder walks again. The "intruder response" to the ambient level is approximately ±10 dB when the intruder is near the rf feed terminal (0°) of the leaky coax cable whereas, it is only ±2 dB when he

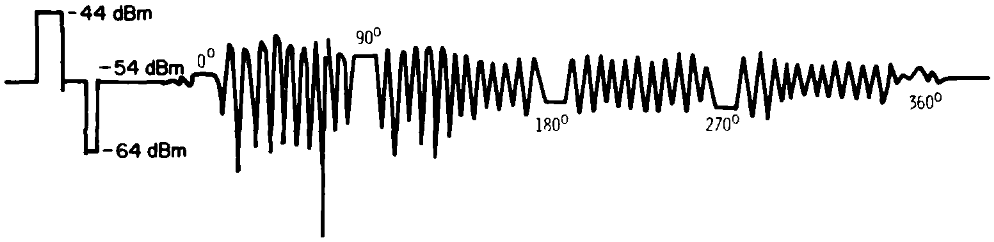

Figure 3a. Power Received by Monopole Located at Center of Loops

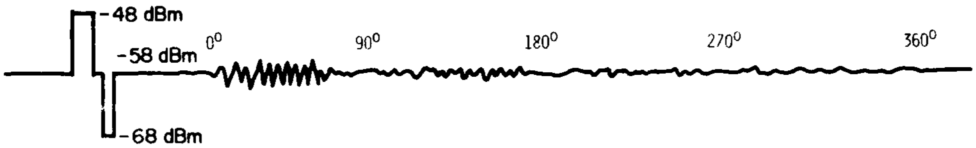

Figure 3b. Power Received by Inner Leaky Coax Cable Loop

is at the end of the cable that is terminated in a matched load. This gradual reduction in "*intruder response*" is due to the attenuation of the rf energy in the coax propagation mode along the cable. The rf energy received from the inner coax cable loop whose circumference is 75 m (as shown in Figure 2) was also suitably monitored in a different channel of the network analyzer. The radial distance betweer the two loops is approximately 12 m. Even when the intruder was walking along the outer leaky coax cable, which is emanating the rf energy, the "disturbance" of the intruder is detected either by the inner loop (up to 90°), or the monopole at the center of the loops. Note that while the ambient levels received by the monopole (-54 dBm) and the inner loop (-58 dBm) are not that different, the relative intruder response of the signals by the two receivers (monopole and inner leaky coax cable) is significantly different.

4.2 Response of Intruder at Leaky Coax Cable Loops Illuminated from Antenna Located at Ground Level and Elevated from Ground

All leaky coax intrusion sensor systems detect the disturbance of the rf fields at the surface but differ in the mechanism by which the surface disturbance "*information*" is conveyed to the receiver. For example, in SWIRPS system the surface wave disturbance fields are either added or subtracted from the space wave fields radiated from the cable to the monopole. The definition of space wave

and surface wave are similar to those defined by Jordan.[21] The earlier SWIRPS studies utilized the centrally located antenna only at the ground level. It is expected that as the antenna is elevated from the ground, multipath effects will add to the disturbed surface wave and space wave interaction. Using the conventional SWIRPS system and two concentric coax cable loops of 150 m and 75 m in circumference, the effect of elevating the antenna from the ground on "intruder response" was tested. These results are shown in Figures 4 and 5. These illustrations (the four traces) show the intruder response when he walked along the 150 m and 75 m perimeter coax cable loops. In both these experiments the monopole, located at the center of the loops, transmitted 80 MHz rf energy from the HP network analyzer (8505), amplified to 2 W. In each of these figures the top trace (a) corresponds to the intruder response when the monopole is located on the ground and the bottom trace (b) to that when the base of the monopole is elevated 2.5 m from the ground. This is not large compared to the rf wavelength 3.75 m. However, the ambient level of rf power received by either of the concentric loops increased by 8 to 10 dB when the antenna was off the ground.

In Figure 4(a, b) the intruder response varied from +5 to -20 dB about the ambient level at the receiving end of the cable and only about ±2 dB at the terminating end of the 150 m perimeter cable. Note that the intruder walked from the receiving point to the terminating point so that the intruder scattered signal lessened due to cable attenuation. Therefore, the intruder response decreased since the ambient signal became greater than the intruder scattered signal. Figure 5(a, b) shows a reversal of the intruder response from that shown in the previous figure because the receiving point and the terminating point were interchanged.

The results show that it is feasible to have a configuration in which the monopole is elevated from the ground. In practical applications it may be advantageous to mount the receiving monopole on the aircraft itself by suction cups or other devices, if permanent mounting is undesirable.

4.3 Illumination of Leaky Coax Cable Loops from a Monopole 15 m Above Ground

Figures 6 and 7 depict the response of an intruder walking circumferentially on two concentric leaky coax cable loops that are illuminated by rf energy radiated from a monopole approximately 15 m above the surface containing the loops as shown in Figure 2. The loops are approximately 8 to 10 wavelengths away from the monopole. The transmitting monopole antenna received rf power (2 W) at 80 MHz from the power amplifier that, in turn, is fed from the 8505 network

21. Jordan, E.C. (1950) Electromagnetic Waves and Radiating System, Prentice Hall Inc., New York, New York, pp. 608-609.

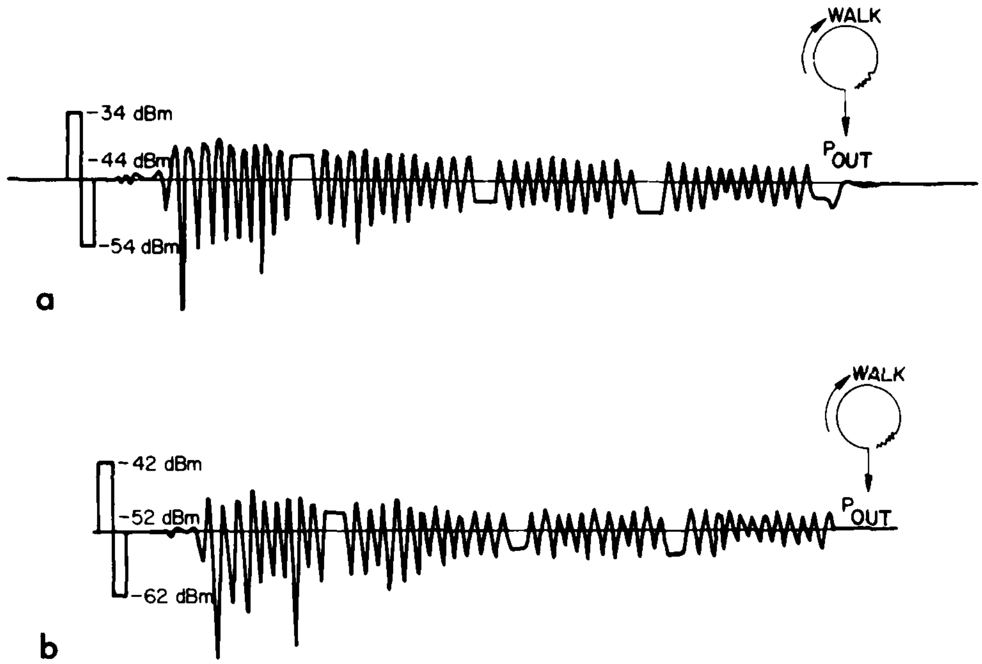

Figure 4. Power Received by 150 m Leaky Coax Cable Loop from Transmitting Monopole (a) On Ground and (b) 2.5 m Above Ground

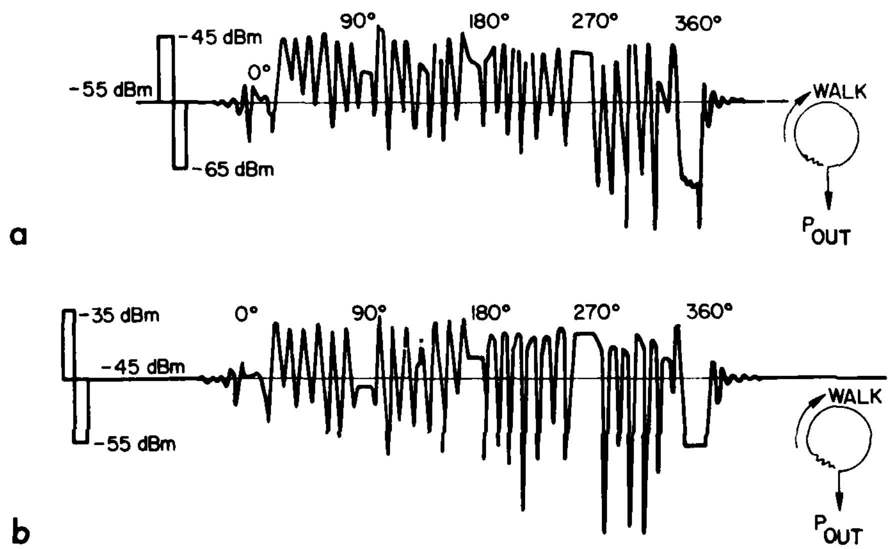

Figure 5. Power Received by 75 m Leaky Coax Cable Loop from Transmitting Monopole (a) On Ground and (b) 2.5 m Above Ground

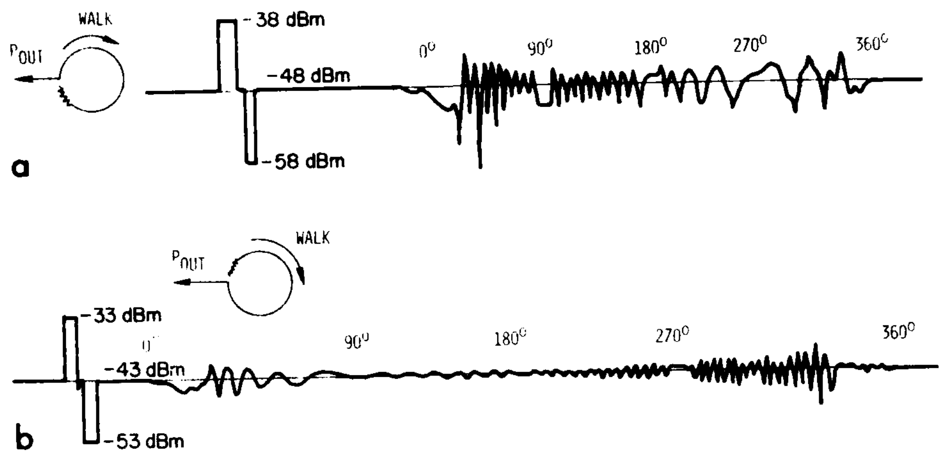

Figure 6. Power Received by (a) 75 m and (b) 150 m Leaky Coax Cable Loop from Monopole 15 m Above Ground

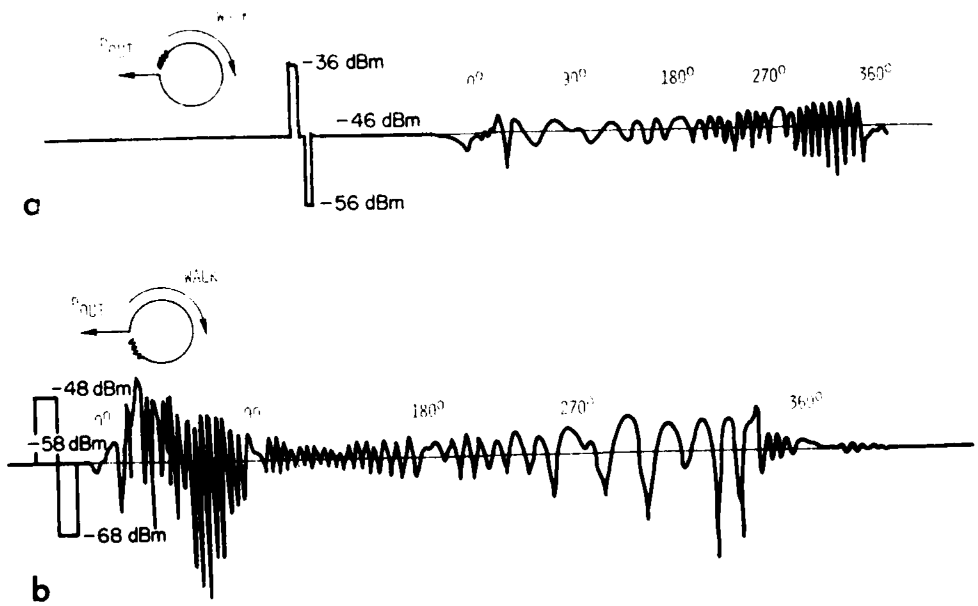

Figure 7. Power Received by (a) 75 m and (b) 150 m Leaky Coax Cable Loop from Monopole 15 m Above Ground

analyzer. The network analyzer was also used as a receiver for the power collected by the illuminated cables. The top traces in both Figures 6 and 7 show the "intruders disturbance" on the ambient level of the power received from the 75 m cable, as the intruder walked circumferentially. The bottom traces in both these figures correspond to the case when the intruder walked on the 150 m cable. The intruder made a circumferential walk always in a clockwise direction, but the different traces in each figure correspond to opposite ends of the cable being terminated with matched loads. The top traces of Figures 6 and 7 show that the intruder's response is very nearly a mirror image as a function of the azimuth position. No significance is given to the 2 dB difference in the ambient level (-48 dBm vs -46 dBm) in these two traces. In all four traces it is noticed that even though the intruder is walking at a constant speed, the frequency of the disturbance varies in different segments of the loop. The frequency is maximum when the intruder is near the receiver and minimum at the point where the leaky coax cable is terminated. When the matched load is interchanged with each terminal of the cable, the intruder response also is reversed. For this set up, the maximum disturbance caused by the intruder is always at a position on the cable where the intruder is nearest to the receiver.

4.4 Use of Leaky Coax Cable as Transmitting Antenna and Two Widely Separated Monopoles as Receiving Antennas

This experiment was performed to see the effect of the "intruder's disturbance" as seen by the two widely separated monopole antennas when the 150 m leaky coax cable was used as a transmitting antenna. One receiving antenna was at the center of the 150 m loop and the other receiving antenna was on top of the building as shown in Figure 2. The top trace shown in Figure 8 corresponds to the amplitude of the rf power received from the monopole antenna at the center of the loop and the bottom trace to that received from the monopole on top of the building. The intruder made a circumferential walk starting from the load end, along the 150 m loop making stops for a few seconds at 0°, 90°, 180°, 270°, and again at 360° azimuthal positions. The "intruder response" is similar to the one shown in the top trace of Figure 3a (except the walk started from feed end). Two differences between the two top traces (Figures 3a and 8a, respectively) have to be mentioned. First, the change in the ambient level of the received power from the ground-based monopole in Figures 3a and 8a. This small change was observed when matched terminations were changed at either end of the cable. Second, the intruder's response was greater in Figure 8a, than that observed in Figure 3a. The amplitude of the variations in the intruder response depends upon the ratio of ambient signal to scattered signal. It is greatest when the two signals are approximately equal and less when the ambient signal is smaller or larger than the intruder

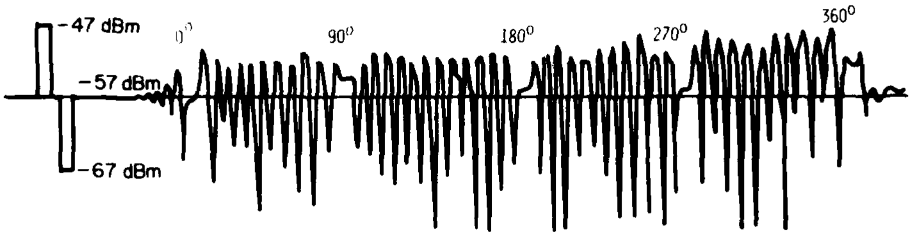

Figure 8a. Power Received by Monopole Located at the Center of 150 m Leaky Coax Cable Loop

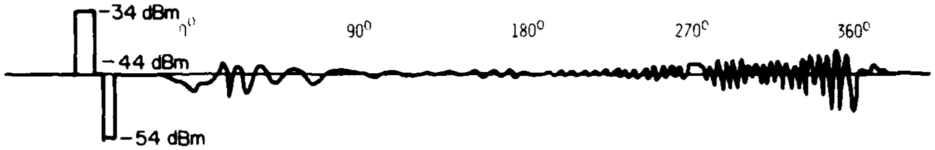

Figure 8b. Power Received by Monopole Located 15 m Above Ground

signal. As mentioned, interchanging the matched load from load end to feed end, changes the ambient level, due to the layout asymmetry, however small, between the transmitting cable the receiving antenna. This asymmetry changes the ambient field path lengths to the receiving antenna and so changes the total received power. It follows that if the ambient field path lengths are changed by any cause (that is, increase or decrease in ground conductivity, frequency change, or physical configuration change) the ambient level will also change. Therefore, the amplitude of the variations in the intruder response will change.

The trace in Figure 8b shows the "intruder's response" as seen by the monopole antenna on the roof of the building. The ambient level has changed, not only due to the changed path lengths of the ambient signal but also, now, due to multipath effects that were not present when the receiving antenna was on the ground. As observed in Figure 8b, the frequency at which the amplitude is modulated varied along the cable length. This effect, caused by the rate of change of received signal phase as a function of intruder position along the cable not being a constant, has been predicted by theory. It was also observed, though not shown in the data in Figure 8, that when the intruder walked on the "unexcited" 75 m cable, the intruder's response was detected by the monopole at the center of the concentric loops. Such a response was not observed when the intruder walked without the inner loop being physically present on the ground. This fact substantiated an earlier conclusion that, at these cable separations, enough coupling existed between the two loops to cause the unexcited inner loop and monopole to respond to an

intruder walking around the inner loop. It should be pointed out that the monopole on the ground is perpendicular to the plane containing the coax loop, whereas that monopole on the roof is parallel to the coax loop. The effect of selective polarization (horizontal or vertical) on system response was not investigated but should be considered in any similar experiments.

4.5 Illumination of Parallel Leaky Coax Cables Laid on Ground: Elevated Monopole Antenna

It has been observed in the previous experiments that concentric loops of leaky coax cables (which are illuminated by rf energy from elevated antennas) can be used as receiving antennas to detect and localize intrusions in annular regions. Using rf energy received from each concentric loop in a multichannel receiver, the annular region in which intrusions occur can be identified.

We have performed experiments on the modified SWEPS [illegible]ct intruders crossing particular parallel leaky coax cables. In Figure [illegible] the layout of two leaky coax cables (40 m and 75 m long) that are laid [illegible] and parallel to each other and separated by 12 m. The mark "X" in F[illegible] corresponds to the ground level position, 15 m above which is locate[illegible]mitting monopole antenna. The intruder walked along both cables from the end points that are terminated by matched loads. Two W of rf energy at 80 MHz were fed into the transmitting monopole antenna. The power received at points P_2 and P_1 is directed into separate receiving channels of the network analyzer. The intruder walked along both cables at approximately the same speed. The frequency at which the amplitude is modulated in both cables was different and also varied as the intruder walked along the cable as shown in Figures 9a and 9b. This is to be expected due to the nonuniform change in the path length from transmitter to receiver via the intruder as he walked along the cable. In contrast to the concentric loops, which were also illuminated from the same monopole, no significant rf coupling occurred between cables. However, rf coupling to one leaky coax cable was observed when the other parallel leaky coax transmitted. Experiments were also performed when the intruder walked across each cable and the "intruder's response" was detected in that particular channel. Thus, instead of concentric loops of leaky coax cable, parallel leaky coax cables can also be used to localize an intruder, either when crossing a particular cable of the parallel set or as being within the area bounded by two of the cables.

4.6 Simultaneous Reception of Intruder's Response from Both Ends of a Leaky Coax Cable

The following experiment was performed to understand the manner in which the illuminated rf wave interaction with the intruder propagates along the leaky

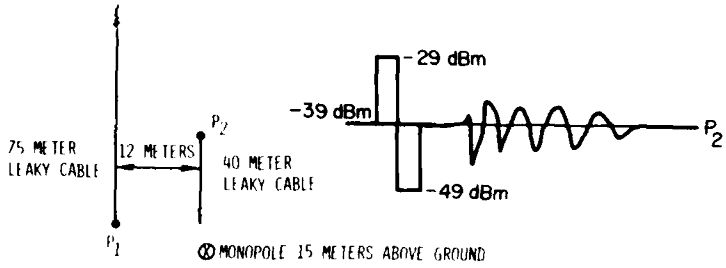

Figure 9a. Power Received From 40 m Cable From a Monopole 15 m Above Ground

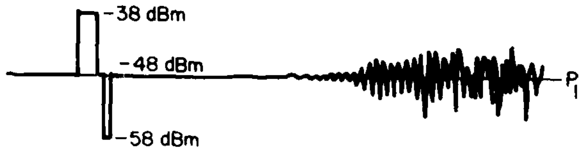

Figure 9b. Power Received From 75 m Cable From a Monopole 15 m Above Ground

coax cable. The 75 m leaky coax cable was laid on the ground perpendicular to the building, as shown in Figure 2. The monopole on the roof of the building radiated approximately 2 W of rf power at 80 MHz illuminating the ground as well as the leaky coax cable. The intruder walked at a steady pace along the 75 m cable from point P_1 to P_2 as shown in Figure 10. The power received from both terminals of the leaky coax cable P_1 and P_2 as the intruder walked along the cable is shown in traces marked P_1 and P_2.

Two characteristics can be identified: 1) the changes in frequency of intruder fluctuations, both within the same walk and also between different walks and 2) the changes in amplitude of intruder fluctuations as predicted by theory (referenced earlier). The frequency of intruder fluctuations depends upon the rate of change of path length from the transmitter to the intruder to the receiver as the intruder moves. If the rate of change is constant (as would be with a circular cable loop and a centered antenna), the frequency of the fluctuations remains the same. As seen in Figure 10(a) [and more clearly in Figure 10(b)] the frequency (within the same walk) changes as a function of intruder position along the cable, which says that the rate of change of phase is not constant. Further, as seen by comparing the frequencies of Figure 10(a) and 10(b), the rate of change of phase changes depending upon whether the intruder moves toward the receiver [Figure 10(a)] or away [Figure 10(b)].

The amplitude of the intruder response fluctuations depend upon the ratio of intruder scattered power to ambient power. In both Figures 10(a) and 10(b), the

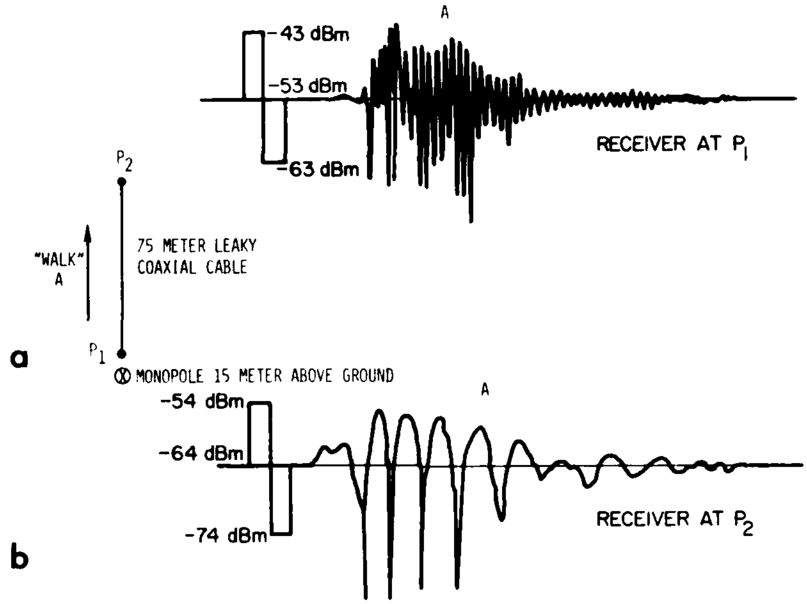

Figure 10. Power Received from One End of Leaky Coax Cable (Monopole Height = 15 m)

amplitude is maximum on the cable nearest the transmitting antenna, implying that the intruder scattered power and the ambient power are the most equal that these two signals will be during this set of measurements. However, further along the cable, the amplitude begins to drop, implying that the intruder scattered power is lessening, so that the total intruder scattered field is lessening. The lessening of scattered intruder power can be attributed to several causes, none of which were experimentally verified but were deduced from past experience with radiating radio frequency systems. First, cable attenuation was neglected because of the short lengths of cable involved. Second, the angular azimuthal pattern of the transmitting antenna was assumed to be constant over the area of the two cables. Third, some loss of scattered intruder power resulted from depolarization effects as the angle between the raised transmitting antenna and intruder changed. The biggest cause of the lessening intruder scattered power was attributed to the free space drop in field intensity of the radiated energy as the intruder moved from one end of the cable to the other.

Figure 11 (a and b) illustrates the same effects as shown on the previous figure, but with a shorter cable.

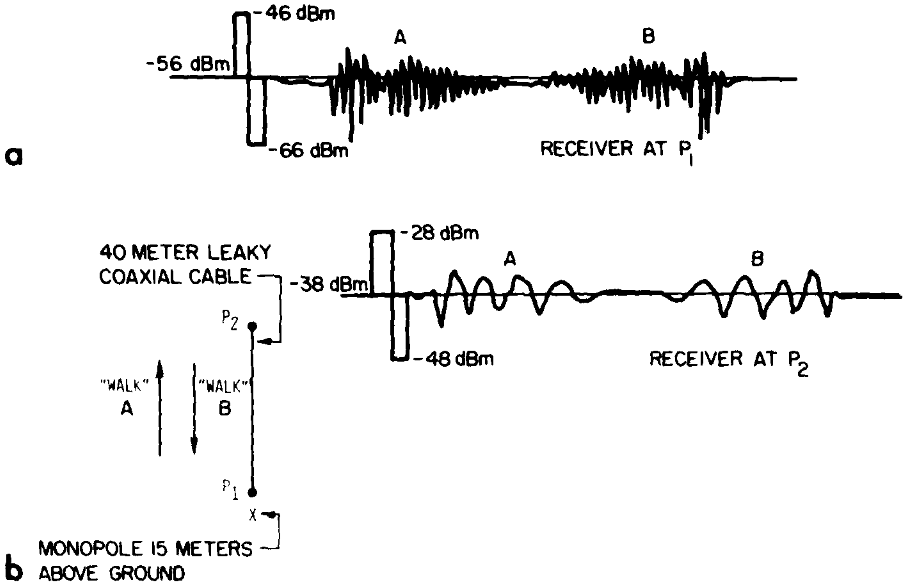

Figure 11. Power Received from One End of Leaky Coax Cable (Monopole Height = 15 m)

4.7 Ambient Signal Equalization by Switching the RF Energy Between the Terminals of the Leaky Coax Cable in SWIRPS System

The single wire intrusion resource protection system (SWIRPS) was designed originally as a portable system. The attenuation factors of low-weight, flexible cables were greater than those for large rigid cables. As reported earlier,[15] in a typical 0.3 km perimeter system the intruder's signal or response at the far end can be 20 dB smaller than that near the input point (for example, Figure 3a). A switching technique[15] has been incorporated into the SWIRPS to reduce the variation in detection sensitivity. A sketch of the switching arrangement is shown in Figure 12. An electronic switch alternately connects the transmitter to one point of the cable or the other. It is clear from the preceding discussion that the detection sensitivity is greatest at the rf input section of the sensor cable. Thus, as the switch alternately connects the transmitter to one side and then the other, the intruder's signal is larger or smaller according to his distance from the respective input. When he is halfway around, the signal is same for both switched positions. By proper processing of the responses the variation in detection sensitivity with intruder's position can be greatly reduced. Further, if several segments of a leaky coax cable loop were excited simultaneously, the intruder response along the entire perimeter would be more uniform and also the intruder would be located by identifying the segment that had been crossed. Figures 13a and 13b show the results obtained when an intruder walked along a 150 m leaky

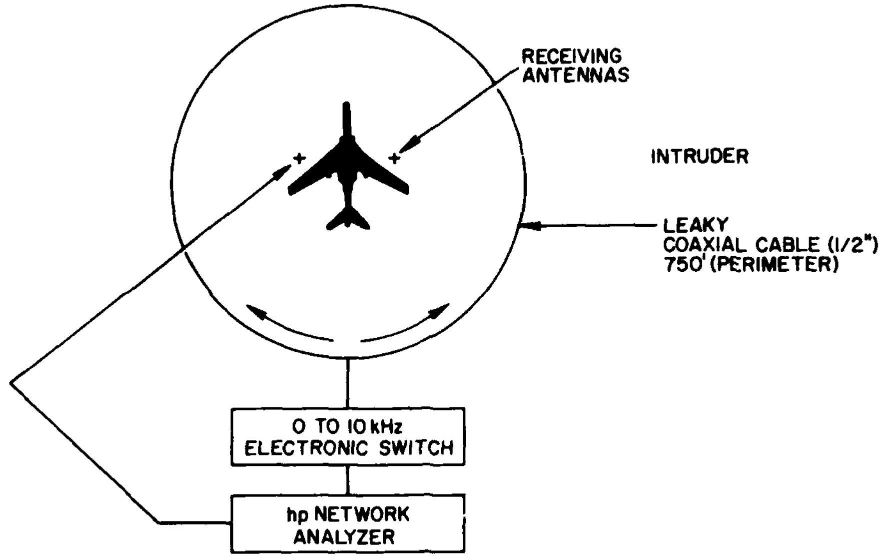

Figure 12. Single Wire Individual Resource Protection Sensor (Switching)

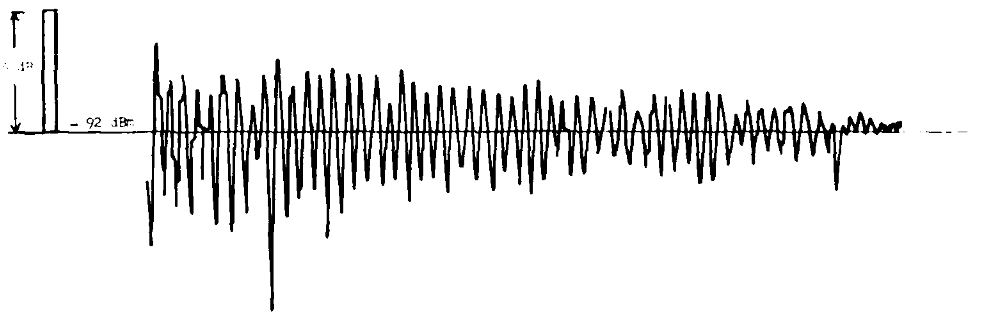

Figure 13a. CERT Cable Loop Fed by 80 MHz from Single End

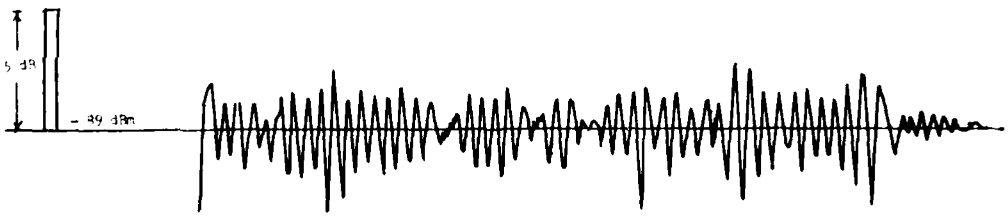

Figure 13b. Effect of 1 KHz Switching Between Terminals of 150 m CERT Loop

coax cable loop lying on gras soil (without an aircraft) and using a single monopole antenna as a receiver at the center of the loop. Figure 13a shows the response obtained when the rf energy is fed continuously from one end of the cable into the load at the other end, whereas Figure 13b is that obtained when rf energy is alternately switched between the terminals of the cable.

The intruder's disturbance, in trace 13b compared to 13a, is reduced; however, the variation in detection sensitivity is also reduced. This more uniform response allows an alarm threshold that does not have to have so low a value at a low sensitivity region that nuisance alarms increase unacceptably at a high sensitivity region.

4.8 Intruder's Response as a Function of Intruder's Location Above the Leaky Coax Cable

An experiment on the modified SWIRPS was performed to determine the height above the illuminated leaky coax cable where the intruder will have negligible response. The 75 m leaky coax cable laid on the ground perpendicular to the building shown in Figure 2 was used for this experiment. Two wooden step ladders supporting a wooden platform, whose height above the leaky coax cable was adjustable were placed near the cable 2 m apart. The step ladders with the wooden platform were located near the building, in other words, at the end of the cable that was nearest to the receiver (HP network analyzer). As the intruder stepped on the wooden platform at a given height and walked on it his response, on the ambient signal level received from the cable, was recorded. The input amplitude of the rf power to the transmitting monopole (on the roof) was +10 dBm and the ambient level received from the cable was -57 dBm.

Table 1 shows the height (platform height above the cable) at which the intruder walked and the normalized (to 0 m) response.

Table 1. Intruder Response vs. Height Above Cable

Platform Height in Meters (m)	Normalized Intruder Response (dB)
0.0	0
0.3	0
0.6	-4
0.9	-5
1.2	-8
1.5	-9
2.0	-9

It is of interest to notice that at elevations greater than 1.5 m above the cable, the intruder had negligible response on the received signal, even though he did scatter the electromagnetic energy radiated from the monopole.

5. SUMMARY OF EXPERIMENTAL RESULTS

The experiments have shown that, in rf intrusion sensor systems, leaky coax cables used as distributed transmitting antennas may couple significant amount of energy to other nearby leaky coax cables. Thus, care should be taken in estimating power levels in order to eliminate unwanted signals in neighboring leaky coax sensor cables. The response of the SWIRPS system to intruders crossing the sensor cables is very much dependent upon the geometrical configuration of the transmitting and receiving elements of the SWIRPS. This observation, though qualitative, is substantiated by abundant experimental results from earlier SWIRPS (using circular and square loops of leaky coax cables) and from this report (Figures 6 through 11). Results shown in Figures 12, 13a, and 13b indicate that the electronic switching of rf energy between terminals of a single cable or segments of several receiving cables may be utilized to improve uniformity of the detection sensitivity. Experiments utilizing parallel segments of the leaky cables or concentric loops of leaky cables have shown that these configurations localize the area in which the intrusion occurs. Data shown in Table 1 shows that leaky cables do not detect intruders above a certain height. This height is the height beyond which the external rf fields have fallen off in amplitude sufficiently to make the scattered signal received by the monopole negligible.

The concept of utilizing multiple receiving elements (leaky coax cables or small dipole antennas) distributed along the annular swath to be protected appears feasible. This statement is based on the results obtained when an intruder crossed rf illuminated parallel leaky coax cables, concentric loops of leaky coax cables, and off-centered multiple antennas located within a single loop of sensor cable. The limited experiments performed in-house utilized multiple channels of the network analyzer, but switching techniques and parallel processing of rf signals from multiple receiving elements would aid in tracking an intruder in large and small areas.

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